A Study on the Performance of 2D and 3D Geogrid Reinforced Sand Under Cyclic Loading

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Abstract: Soil reinforcement and soil confinement are the methods in ground improvement techniques, these methods are commonly adopted in geotechnical engineering to stabilize the soil. In the present investigation plain-geogrid acts as reinforcement material and geogrid with pipes act as confined reinforcement system to enhance the load settlement behavior of the model square footing. Also studied the effect of spacing between reinforced layers and number of geogrid (2D) reinforced layers and geogrid with PVC pipe(3D) reinforced layers. Comparisons were made to know the effectiveness of inclusion of PVC pipe in geogrid layer on the enhancement in the load settlement behavior of model footing on sand bed under repeated loading.

Keywords: Settlement ratio; Cyclicresistance ratio; S/B ratio; U/B ratio; Repeated loading; Geogrid; PVC pipes; Reinforced Sand Bed.

1. INTRODUCTION

Soil reinforced and soil confinement is the methods in ground improvement technique, the construction which is by inserting reinforcement material to the soil. It was first introduced by Henry Vidal a French engineer in 1966. Now there are many types of reinforcements available, generally they are made from either steel or plastic, although glass–fiber strips and other composite materials are used. More recently, polymer reinforcements have been gaining popularity used in long-term retaining walls. These high strength polymers include forms of polyethylene (geogrids), polypropylene (Geotextiles) and polyester (Geotextiles and Geocomposites).

1.1 Literature review

Several investigators reported that a significant increase in the bearing capacity and a reduction in settlement of footing were obtained from the addition reinforcement and by confining the soil. The Bearing capacity ratio (BCR) was increased with incretion of Geo-synthetic material as a reinforcement Adams, Collin J.G & M.T (1997)[1], Increases in the bearing capacity of soil by insertion of skirt as a confinement H. Mahiyar and A. N Patel[4], Reduces the settlement of footing by providing the confinement to the soil bellow the footing, the effectiveness of load carring capacity of soil decreases with increases in the size of the confinement below the footing Vinod Kumar Singh et al[13], increasing the strength of granular soil by insertion of geocell confinement and also it increasesthe stiffness of the granular soil S Dash, N Krishna Swamy and K Rajgopal [8]. The bearing capacity of sand increases by 8 times due to insertion of the geocell S. K. Dash, S. Sireesh, T. G. Sitharam [9],Sujith Kumar Dash et al,.(2003)[11].Sreedhar M. V. S and A. Pradeep Kumar Goud (2011)[10], Erol Guer et al,.(2015)[3]. Decrease in the settlement of footing with addition of number of reinforcement layers has been observed, Basudhar, Santanu Saha, and Kousik(2007)[2]. Improvement in load bearing capacity of circular footing resting on fly ash reinforced sand bedsTejaswini B. R, S. Gangadara, H. C. and Muddaraju, (2014)[12]. Geocell as a reinforcement layer increases 10 times in Bearing capacity, 8 times in the stiffness and 90% reduction in the settlement, Lalji Baldaniya(2005)[5]. The investigations were made using Geogrid and skirts, Geogrid increases the stability and stiffness of the substructure and skirt provide confinement and increases the stability of the substructure Monsour Mosallanezhod(2008)[6],Sareesh Chandrawanshi, Sudhakar and Jain(2014)[8]. The inclusion of skirt tends to increase in bearing capacity of soil and reduces in the settlement of footing also studied the thickness of skirt, shape of skirt using Finite element analysis M. F. Bransby and M. F. Randolph[7] In the present study Geogrid is used as a reinforcement and pipes as a confinement to the soil, together Geogrid and Pipes act as a confined reinforcement system, in this system geogrid resists the tensile stress and pipes reduces the lateral movement of sand during the application of load. The objective of the study is to know the effect of reinforcement in 2D(geogrid) and 3D(geogrid with pipes) format on the performance of model square footing resting on reinforced sand bed, to achieve this objective 18 model tests were carried out on unreinforced and reinforced sand bed.

2. TEST MATERIALS

Table 1. Properties of sand

Properties	Test Result
Particle size distribution	
Silt and clay (%)	0.2
Sand (%)	99.8
Gravel (%)	0
Uniformity coefficient(Cu)	2.89
Coefficient ofgradation(Cc)	0.96
Natural dry density, (kN/m^3) at 46 % Relative density	15.4
Specific gravity(G)	2.62
Angle of internal friction(degrees))	36
Minimum dry density(kN/m^3)	14.95
Maximum dry density(kN/m^3)	17.7

Table 2. Properties of materials

Parameters	Value
Geogrid	
Thickness at Joints (mm)	5
Thickness at Rib (mm)	2.4
Geogrid size (diameter in mm)	480
Structure	Hexagonal aperture Bi oriented, mesh type
Tensile strength (kPa)	7.74
Aperture size at junction (mm)	26.1
PVC Pipe (garden hose)	
Density (g/cm)	1.40
Inner diameter of pipe (mm)	18.8
Thickness of pipe (mm)	2.6
Mild steel footing	
Size of footing (square)	100x100mm
Thickness of footing	4mm
Mild steel tank	
Internal diameter of tank	500mm
Internal height of tank	390mm

3. TEST METHOD

3.1 Preparation of sand bed

Unreinforced sand bed is prepared by vibratory compaction of sand in three layers up to the height of tank(360mm) by sand raining technique. Reinforced sand bed is prepared by placing geogrid at specified depth and spacing in a sand layer from the base of footing. The geogrid is placed in such a way that there is no friction between the wall surface of the tank and reinforcement. The model square footing is placed centrally on the top surface of the prepared sand bed in model tank, the model tank having internal diameter five times the size of footing to avoid confinement effect from the model tank.

3.2 Test procedure

The tests are conducted in an Automated Dynamic Test Apparatus (ADTA) is used for repeated load application on footing. ADTA is specially designed, fabricated and calibrated for the present work. The maximum load capacity of the equipment is 20kN and maximumfrequency of 2Hz (interval of 0.1Hz), the other characteristic of the equipmentbeing its capability to generate three different type of loading waveforms (Square, Sinusoidal and Sawtooth). The software used in the system is "MOVICON-9.1". Software which controls the ADTA equipment and it is capable of generating above three different wave type of loading waveforms. The test sample is subjected to repeated loading through model footing resting on unreinforced and reinforced sand bed. The desired pressure, frequency and waveform are the input to the system through ADTA. The repeated load is applied on the model square footing and displacements were measured in terms of settlement using LVDT's placed orthogonal to each other. The LVDT's and load cell are connected to the control unit, where analog to the digital conversion takes place and is recorded in data acquisition system. Thus all the load application and response measurement are automated.

3.3 Geogrid system (3D)

Soil confinement and reinforcement system is expected from arrangement of PVC pipes and geogrid. PVC pipes are placed perpendicular to the geogrid layer. Here geogrid act like a reinforcement and pipes as confining material. The geogrid system resists the tensile stress and pipes reduce the horizontal movement of sand during the application of load.

Figure 1: Geogrid-PVC Pipe system

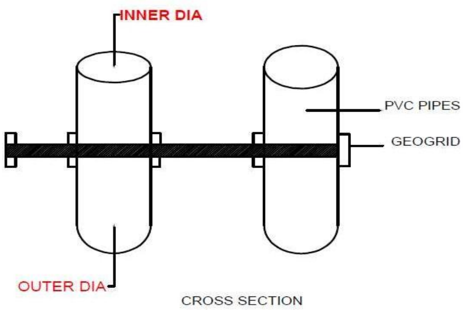

Figure 2: Cross section Geogrid with PVC pipe system

4 RESULTS ANDDISCUSSIONS

In order to understand the performance of model footing resting on Geogrid reinforced sand bed, factors taken into consideration are (i) Depth of 1st layer of reinforcement(ii) Spacing of the reinforcement layers i.e., S=0.3B, 0.4B & 0.5B, where B is breadth of footing (iii)Number of reinforcement layers (N=0, 2 & 3), (iv) Height of confinement in 3D (PVC pipe height H=2cm).A cyclic load of 300kPa for a frequency of 2Hz is applied.Testsare conducted for different U/B ratios in both 2D and 3D reinforced condition. The depth of first layer of reinforcement from the footing level is found to be effective at 0.4times the width of the footing i.e., U=0.4B for both 2D and 3D reinforced condition.

4.1 Effect of reinforcement configuration of 2D geogrid

4.1.1Effect of spacing of reinforcement (S) and effect of number of layers reinforcement layer (N)

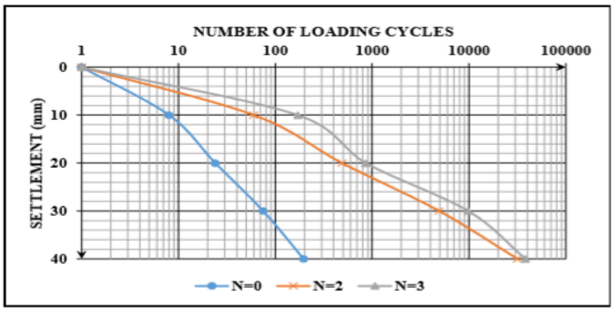

Figure 3: Effect of 2D geogrid on settlement of footing resting on reinforced sand bed under repeated load of 300kPa, f=2.0Hz ,U=0.4B and S/B=0.3

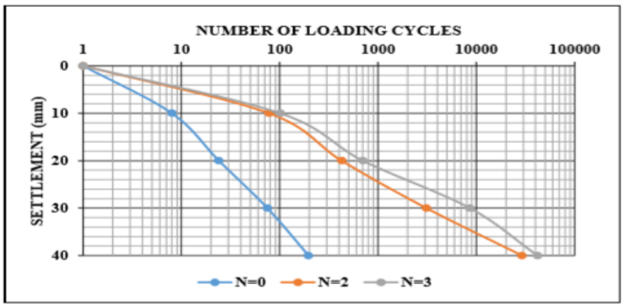

Figure 4: Effect of 2D geogrid on settlement offooting resting on reinforced sand bed under repeated load of 300kPa, f=2.0Hz , U=0.4B and S/B=0.4

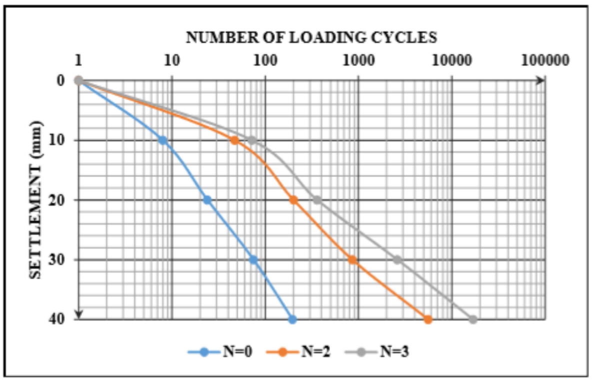

Figure 5: Effect of 2D geogrid on settlement of footing resting on reinforced sand bed under repeated load of 300kPa, f=2.0Hz, U=0.4B and S/B=0.5

It can be seen from Figure 3, Figure 4 and Figure 5 the number of load cycle resisted by model square footing on unreinforced sand bed is only 196 for achieving the 40mm settlement whereas the footing on sand beds with reinforcement layers 2 and 3 takes 31707 & 38395 for S=0.3B, 29198 & 41820 for S=0.4B and 5589 & 22250 for S=0.5B respectively.This shows the effectiveness of the inclusion of geogrid reinforcement in the performance of model square footing on sand bed, with increase in number of layers of geogrid the contact area and the interlocking between the geogrid and soil increases. This conforms that 3layered 2D geogrid reinforcement system perform effectively at reinforcement spacing of 0.4B

4.2 Effect of 3D geogrid reinforcement configuration

4.2.1 Effect of spacing of reinforcement (S) and effect of number of reinforcement layer (N)

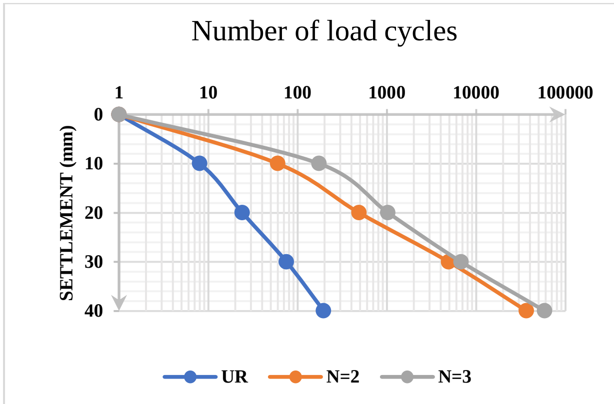

Figure6: Effect of Geogrid and PVC pipes layers on settlementof model square footing resting on 3D Geogrid reinforced sand bed under repeated load of 300kPa, H=2cm, f=2.0Hz, U=0.4B, S=0.3B.

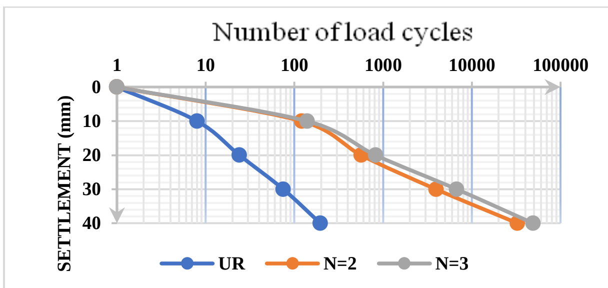

Figure7: Effect of Geogrid and PVC pipes layers on settlement of model square footing resting on 3D geogrid reinforced sand bed under repeated load of 300kPa, H=2cm, f=2.0Hz, U=0.4B, S=0.4B.

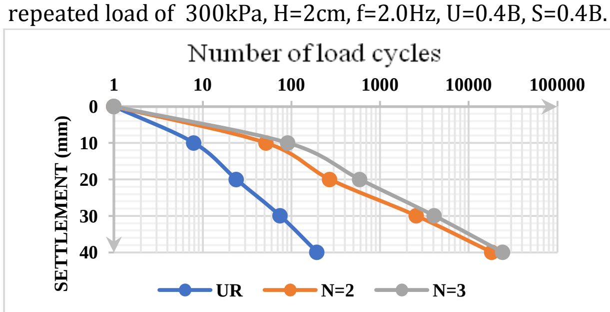

Figure8: Effect of Geogrid and PVC pipes layers on settlement of model square footing resting on 3D geogrid reinforced sand bed under repeated load of 300kPa, H=2cm, f=2.0Hz, U=0.4B, S=0.5B.

It can be seen from Figure 6, Figure 7 and Figure 8 the number of load cycles resisted by model footing on unreinforced sand bed is only 196 for achieving the 40mm settlement whereas the footing on sand beds with 3D geogridreinforcement layers 2 and 3 takes 36669&58732 for S=0.3B, 32800&49234 for S=0.4B and 18355&24306 for S=0.5B respectively. This result shows the effectiveness of the insertion of 3D geogrid reinforcement in the performance of model square footing on sand bed, with increase in number of layers of 3D geogrid provides more confinement to the soil. It is observed that lesser the spacing between the layers better the load carrying capacity, this confirms that 3layered 3D geogrid reinforcement system perform effectively at reinforcement spacing of 0.3B

4.3 Comparison of plane geogrid(2D) and geogrid with PVC pipe (3D) reinforced sand bed

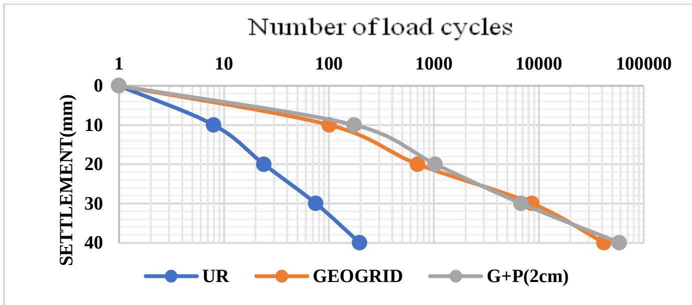

Figure9: Comparison of performance of model square footing on plane geogrid(2D) and geogrid with PVC pipe (3D) reinforced sand bed under repeated load of 300kPa, f=2.0Hz at their optimum condition

It can be seen from Figure 9 the load cycles resisted by model square footing on unreinforced sand bed is 196, in geogrid(2D) reinforced sand bed is 41820 and geogrid with PVC pipe (3D) reinforced sand bed is 58732 for achieving the 40mm settlement. The number of load cycles of (3D) reinforced sand bed is 16912 more compared to that of (2D)reinforced sand bed.The observation clearly shows that the inclusion of geogrid with PVC pipes is more effective when compare to plain geogrid in the increasing of cyclic load settlement characteristics of square footing, as the inclusion of pipe confines the sand which results in increase in development of horizontal stresses and increasing the frictional resistance against the failure.

4.3 Cyclic Resistance Ratio (CRR)

It is the ratio of the number of loading cycles resisted by the reinforced sand beds to the number of loading cycles of the unreinforced sand beds at the same settlement levels.

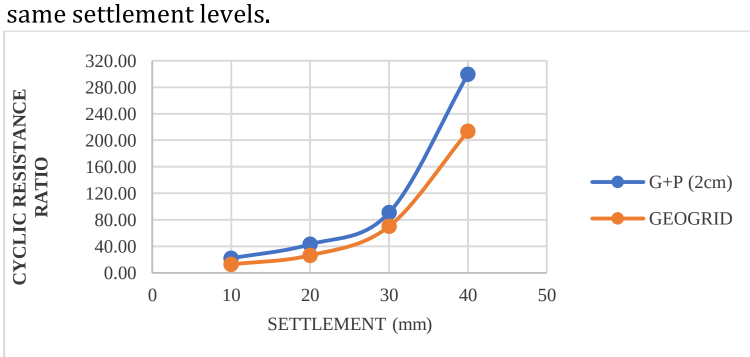

Figure10: CRR of 2D and 3D reinforced sand bed under repeated load of 300kPa, f=2.0Hz at their optimum condition

From the figure 10 indicates that number of loading cycles resisted by 3D geogrid reinforced sand bedhigher than the 2D geogrid reinforced sand bed. Reason as explained in the effect of 2D and 3D geogrid configuration.

4.4 Settlement ratio (SR)

The optimum number of reinforcement layer and spacing of the reinforcement layer are further verified by the settlement aspects in terms of settlement ratio(SR). It is the ratio of settlement of reinforced sand bed after N number of cycles to the settlement of unreinforced sand bed after same number of cycles N.

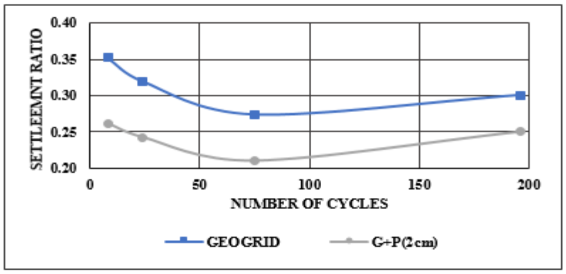

Figure11: SR of 2D and 3D reinforced sand bed under repeated load of 300kPa, f=2.0Hz at their optimum condition

Figure 11 indicates that SR of 3D is decreasing than the 2D geogrid reinforced sand, which states that settlement in 3D condition is less than the settlement that has occurred in 2D condition.

5. CONCLUSIONS

- In general, reinforced sand beds performed better than the unreinforced sand beds regard less of the number of reinforcement layers and spacing of the reinforcement under repeated loads.
- Based on the reinforcement configuration provided
  - For 2D reinforced sand bed: Footing with U/B=0.4, N=3, S/B=0.3
  - For 3D reinforced sand bed: Footing with U/B=0.4, N=3, S/B=0.4

  Exhibited better results compared to the other reinforcement configuration.
- The value of CRR increases and SR decreases with increase in reinforcement layer in both 2D and 3D conditions.
- Performance of footing on geogrid-pipe system is better than the footing on plain geogrid reinforced sand beds. Which exhibits better improvement in increasing the resistance against the loading and also reduces the settlement of footing repeated loading conditions.

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